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RECOGNIZING TRIANGLES, PARALLELOGRAMS, AND CIRCLES
OF ARBITRARY SIZE AND ORIENTATION WITH
HEXAGONAL UNIDIRECTIONAL ARRAYS

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Overview

In a previous paper^{*} we had described

- a) how a unidirectional hexagonal class K network consisting of modules with limited logic and memory and connected to each other with one-way channels can achieve non-addressed directed response and
- b) how such a network can be used to recognize the angular orientation of a line.

Here we shall undertake to show that with few modifications of the rules triangles, parallelograms and circles can be recognized.

Brief Summary of the Previously Described Rules^{***}

In a pattern recognizing hexagonal class K network only the three corners A, B, C as shown in Figure 1 start general messages. A general message is really an information request.

Because of the geometry of the network the general message reaches all non-peripheral modules on two of the three incoming channels simultaneously. When a module that is not within the boundaries of an image, "quiescent module," receives the general message, it propagates it on all outgoing channels. When a module that is within the boundaries of an image, "turned-on module," receives a general message, it codes it (e.g. by complementing it) and propagates the coded general message on all outgoing channels.^{**} If a quiescent module receives a coded general message,

^{*}Sahin, Kenan E., "Detection of Angular Orientation of a Line Using a Hexagonal Selcuk Network," Working Paper 468-70, Sloan School of Management, MIT, 1970.

^{**}The code simply indicates that the module that is passing on the general message is turned-on.

^{***}Patent is pending for non-addressed communication methods as well as recognition methods described here.

the message is uncoded and propagated on all outgoing channels.

The turned-on module that receives uncoded general messages on both channels first propagates a coded general message. Then it emits a response, routing it according to rules described in Sahin^{*}. These rules are such that even though they are locally and independently applied by each module in routing the response, the response gets to the corner that had emitted the general message, without any cycles.

After having emitted a general message a corner receives at least one response (of course if there is an image imposed on the network). A corner that receives more than one response is said to be activated.

In the case of a line, depending on the angular orientation, exactly one of the corners A, B, C becomes activated unless the angle is 0° , or 60° or 120° . In that case none of the corners become activated; that is, all three corners receive single responses.

Modifications to Allow for the Recognition of a Parallelogram, Circle or a Triangle

Previously it was assumed that a figure is imposed on the network and the corners A, B, and C (see Figure 1) emit general messages (that is to say view the figure) sequentially.^{**} With this scheme there can be at most $2 \times 2 \times 2 = 8$ possible patterns of corners which is not enough to

^{*} Sahin, op. cit.

^{**} Simultaneous viewing is also possible but at the expense of more complicated rules and more module memory.

discriminate the multitude of patterns we want to consider. Having the corners A' , B' , C' also view the figure would substantially increase the possible number of corner patterns. However, an examination of Figure 2 will reveal that if A' , B' , C' were to emit general messages, the two channels bringing in the general message to a module would not be the same for all the modules. That is corner A' would behave in part like B and in part like C.

To make use of corner A' , we can either rotate the figure or the network by 180° . This will bring A to where A' was. If we let A view the figure a second time, this will be like letting A' in the original set up view the figure. Same is true of B and B' , and C and C' .

What we are doing is this: 1) We are letting A, B, and C view the figure sequentially and 2) after a 180° rotation of the figure we are letting A, B and C view the figure again sequentially. This is exactly equivalent to having each corner of the six corners A, A' , B, B' , C, C' view the figure.

From now on we will assume that each corner is able to view the figure and will talk about corner patterns where the reference is to those corners that were activated, i.e. that received multiple responses.

Recognizing Triangles and Parallelograms

Assume that the task is to recognize a solid triangle of arbitrary size, and angular orientation. Of course the image of the figure must fall within the network.

It was shown in Sahin^{*} that an edge will activate at most one corner. Therefore a triangle will activate no more than three corners since it has only three edges. Since no two edges of a triangle are parallel, no two opposite corners can be activated. If, for example, A is activated then A' will not be activated.

Hence a triangle's corner activation pattern will have at most three activated corners with no pair being opposites.

In the case of a parallelogram, since there are four edges at most four corners will be activated. Also when a corner is activated its opposite must also be activated since for every edge facing a corner there is a parallel edge facing the opposite corner. And we modified the network as described previously so that opposite corners had the same sensitivity ranges.

Thus for a parallelogram at most four corners will be activated such that if a corner has been activated its opposite must also have been activated.

Recognizing a Circle

A circle appears the same no matter which corner views it. If its curvature is such that one corner was activated, then it follows that all corners must have been activated. If the curvature is not big enough to generate multiple responses to a general message, then none of the corners will be activated.

* Sahin, op. cit.

Thus for a circle either all of the six corners will be activated or none.

Resolution of Ambiguity

An edge that is parallel to one of the sides of the network will not activate any of the corners. And when a triangle or a parallelogram has edges all of which are parallel to the sides of the network, none of the corners will be activated. This is illustrated in Figure 3. Also when the curvature of a circle is below a certain level, again none of the corners will be activated. The result is ambiguity when a figure fails to activate any of the corners. It could be a triangle, parallelogram or a circle. However the ambiguity can be quickly resolved if the figure or the network is rotated by 30° . In that case if the figure was a solid

- 1) triangle, at most three, at least one corners will be activated with no pair forming opposites.
- 2) parallelogram, at most four, at least two corners will be activated where for every activated corner its opposite will also have been.
- 3) circle, then the corner activation pattern will remain unchanged.

General Comments

As yet only three classes of figures are recognizable by the network. And only one figure at a time can be imposed. However it is worth stressing that

- a) the recognition is built right into the network as opposed to a central processor achieving the recognition through a lengthy routine. The corners in our network perform very simply processing.

- b) the arbitrariness in the size and orientation of the figures does not affect the simplicity of the recognition process or the simplicity of the differentiating criteria.

In a forthcoming paper we shall discuss procedures which will allow the network to recognize several figures of assorted combinations of triangles, parallelograms and circles, simultaneously.

Clearly so far we have relied only on whether a single response or multiple response is received. The actual number of responses and the timing of these have been ignored. Taking them into account could allow better discrimination of figures as well as allowing approximate determination of size and location within the network. Research is proceeding along these directions.

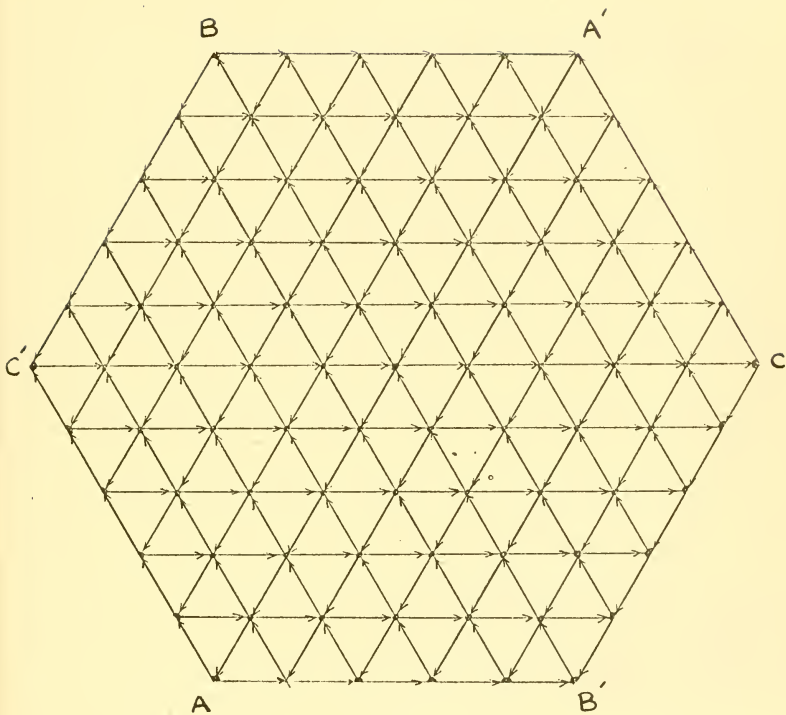


Figure 1

Hexagonal Class K Network

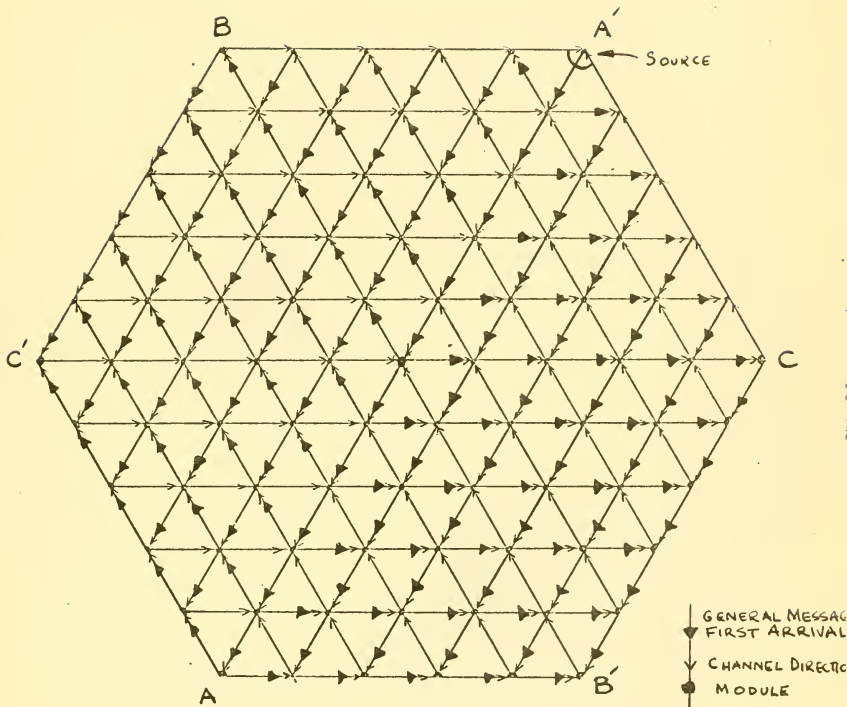


Figure 2

Propagation Pattern of a General Message
Emitted from Corner A'

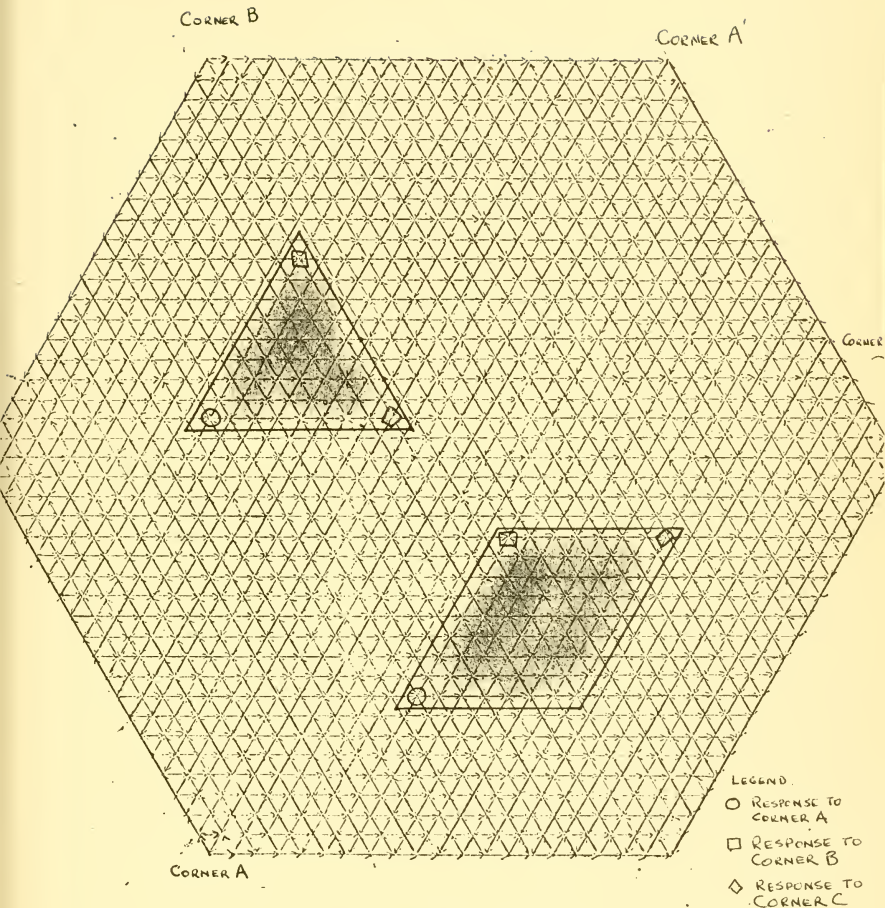


Figure 3

A Triangle and a Rectangle with Edges Parallel to Sides of Network. Only a Single Response is Received by Each Corner for Each Figure. Figures are Imposed Sequentially.

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